International Comparison of Fire Resistant Conveyor Belts

Bernd Küsel

PHOENIX Conveyor Belt Systems GmbH, Hamburg, Germany

Pittsburgh, March 2007

1. PHOENIX Company Overview
2. Conveyor Belt Families
3. Elastomers and their Properties
4. International Approval Tests
5. Experience with self-extinguishing Conveyor Belts
6. Outlook

1.1 PHOENIX Background

- ✓ More than 100 years of conveyor belt design and production.
- ✓ Focused on mining. Belt factories for coal mining in Germany, China and India.
- ✓ Supplier of all outstanding conveyor belts (strongest, longest, heaviest etc., → World Records)
- ✓ First self-extinguishing PVG conveyor belt worldwide (approved 28 years ago).
- ✓ First self-extinguishing steel cord conveyor belt worldwide (22 years ago for Göttelborn mine).
- ✓ First self-extinguishing steel cord conveyor belt as per new strict requirements for Australia (19 years ago for Moranbah mine).
- ✓ First self-extinguishing steel cord conveyor belt for China (12 years ago for Chengzhuang mine).

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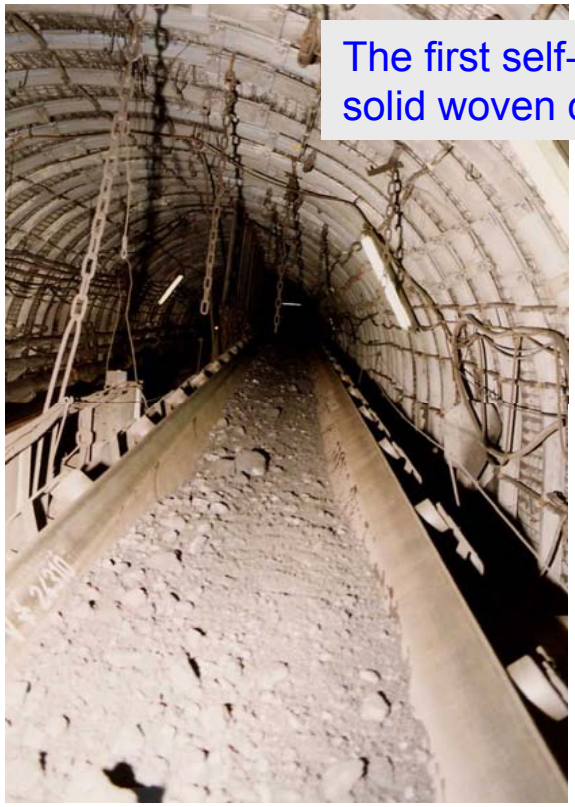
1.2 Highlights in Underground Mining

The first self-extinguishing steel cord conveyor belt



The first self-extinguishing solid woven conveyor belt

The strongest underground conveyor belt

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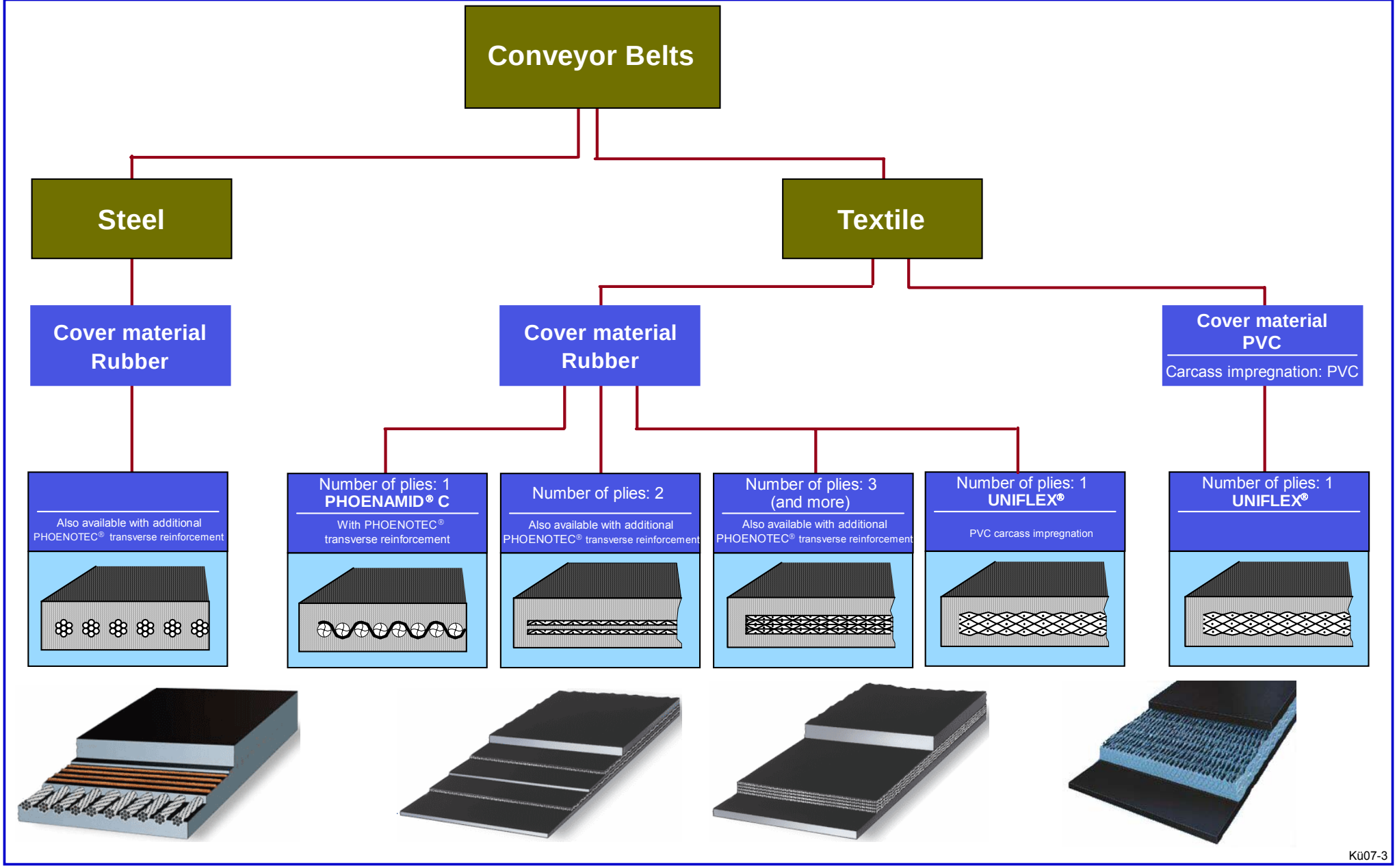
1.3 PHOENIX in US Underground Coal Mining

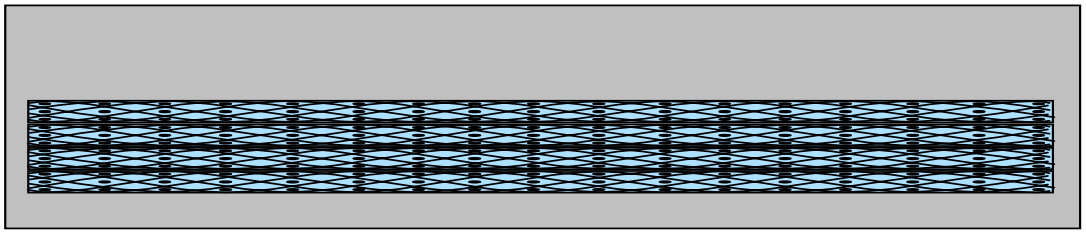
PHOENIX Conveyor Belt Systems GmbH

- is a major supplier of MSHA approved textile conveyor belts for the Central Appalachian Coalfields;
- supplied MSHA approved drift steel cord conveyor belts for Consolidation Coal‘s Enlow Fork and Bailey mines;
- has been supplying conveyor belts to US coal mines for 10 years.

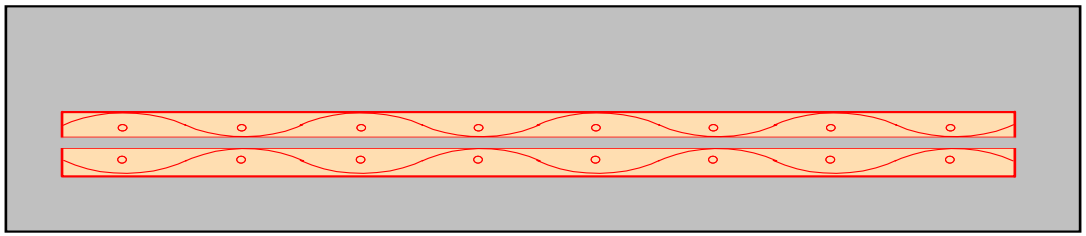
2.1 Conveyor Belt Families



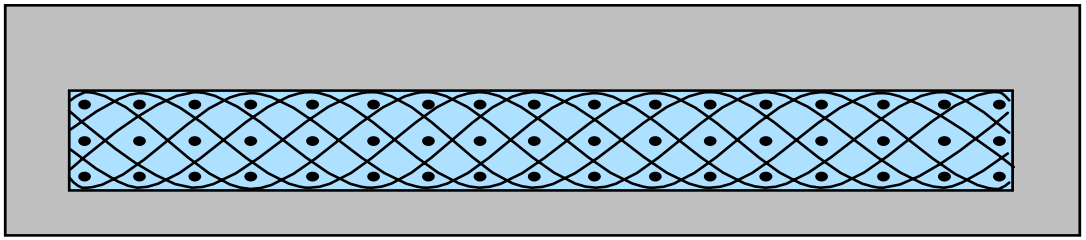
2.2 Textile Conveyor Belt Carcass Types



Multi-ply Conveyor Belt
(*the usual type of belt in the USA*)



Two-ply Conveyor Belt
(*more modern type, also frequently used in the USA*)



Mono-ply (solid woven) Conveyor Belt
(*most modern type*)

3.1 Common Rubber Types

Conveyor belt covers consist of 10 to 20 different ingredients.
The main component is one or more elastomers:

BR	Polybutadiene rubber
CR	Poly-β-chlorobutadiene rubber (e.g. Chloroprene, „Neoprene“)
EPM	Copolymer of ethylene and propylene
EPDM	A terpolymer of ethylene, propylene and a di- or polyene
IIR	Copolymer of isobutylene and diene (butadiene or isoprene rubber -„Butyl“)
IR	Synthetic cis-polyisoprene rubber
NBR	Copolymer; acrylonitrile and butadiene rubber (e.g. Nitrile)
NR	Cis-polyisoprene natural rubber
SBR	Random copolymer of styrene and butadiene rubber
PVC	Polyvinylchloride (a Plastomer!)

Taken from www.ConveyorBeltGuide.com

Other components are carbon black, sulphur, accelerators, fire retardants, antioxidants, fillers, oils, plasticizers, stabilizers etc.

3.2 Basic Properties of Common Rubber Types

1 = excellent 6 = inadequate	BR Butadiene	CR Chloroprene	IIR Butyl	NBR Nitrile	NR Natural	SBR Styr. But.	EPDM Ethyl. Prop.	PVC Plastomer
Breaking strength	4	2	3	2	1	2	3	5
Elongation at break	3	2	2	2	1	2	3	5
Abrasion resistance	1	3	4	2	4	2	3	4
Tear resistance	5	3	3	3	2	3	3	5
Cold flexibility	2	4	2	4	2	3	2	6
Heat resistance	3	2	1	2	4	4	1	5
Weather resistance	3	2	3	4	4	4	1	2
Oil resistance	6	2	6	1	6	5	6	2
Flame resistance	6	2	6	6	6	6	6	2

Taken from www.ConveyorBeltGuide.com

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3.3 Fire resistance – CR, PVC, SBR

International Covers

Since polychloroprene rubber (CR) is highly fire resistant by nature,
only a little amount or no addition of fire retardants is necessary.
In case of a fire, thanks to the high content of halogens (chlorides, bromides),
endothermal processes are initiated which withdraw energy and extinguish the fire.

Polyvinylchloride (PVC) shows a similar behavior.

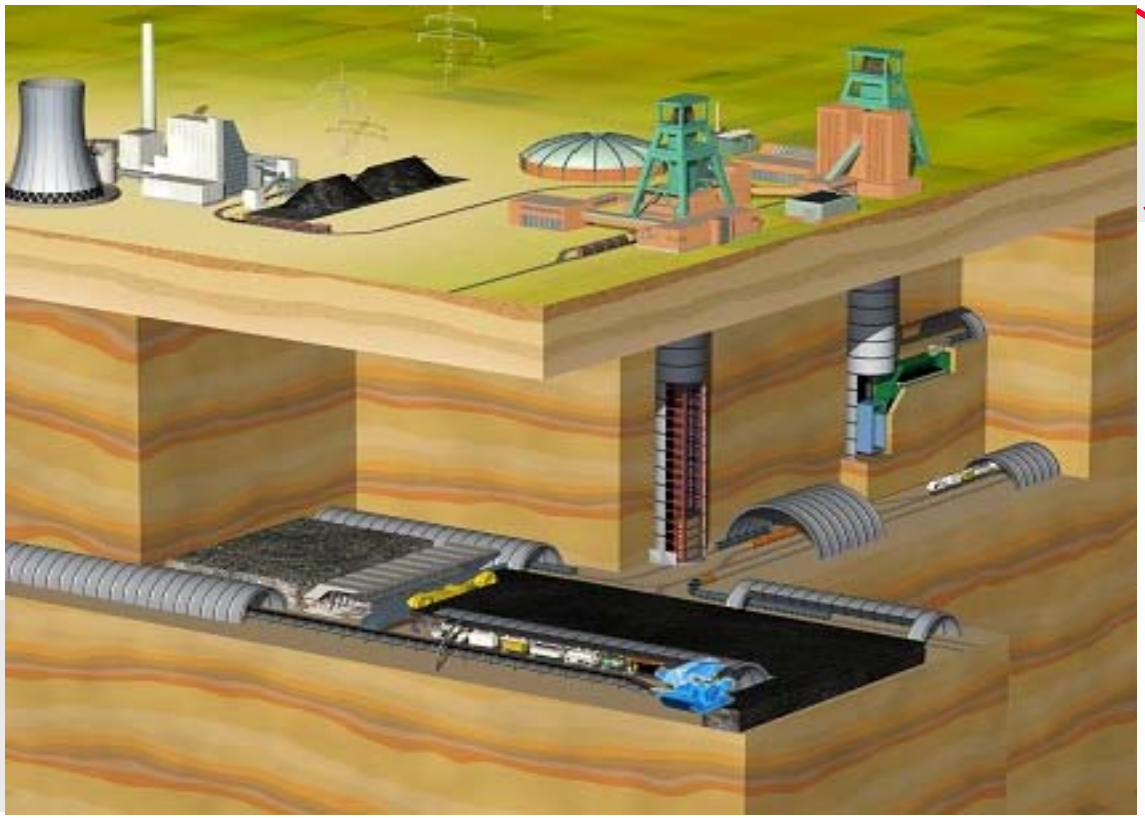
MSHA Covers

In case of styrene butadiene rubber (SBR), a big amount of fire retardants
has to be added, which deteriorate the physical properties of the compound.
Even by addition of big amounts of fire retardants the safety features of CR
cannot be achieved.

3.4 Replacement of Flame Retardant Conveyor Belts

Some 30 years ago, the flame retardant conveyor belts (grade DIN-K or ISO 340) based on SBR - these grades are similar to the existing MSHA grade - had to be replaced by self-extinguishing conveyor belts based on CR in European underground coal mining.

Since then the use of flame retardant conveyor belts was only allowed above ground.



Flame retardant belting

Self-extinguishing belting

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4.1 Biggest Coal Producing Countries And Their Safety Requirements

PHOENIX Conveyor Belts

Country	Production (Mt, 2005)	Conveyor Belt Safety Requirements
China	2226	+++
USA	951	+
Europe	737	+++
India	398	+++
Australia	301	+++
South Africa	240	++
Russia	222	++

4.2 International Conveyor Belt Safety Tests

Test	China	USA	India	Australia	Europe	South Africa	Russia
Drum Friction	yes	no	yes	yes	yes	yes	yes
Propane Grate Burner	yes	no	yes	yes	yes	no	yes
High-Energy Propane Burner	yes	no	no	no	yes	no	no
Large Scale Gallery	no	no	no	no	yes	no	no
Laboratory Scale Gallery	no	proposed	no	no	yes	no	yes
Bunsen/Spirit Burner	yes	yes	yes	yes	yes	yes	yes
Surface Resistance	yes	no	yes	yes	yes	yes	yes
Toxicity	no	no	no	no	yes	no	yes
Oxygen Index	no	no	no	yes	yes	no	yes

Note: In most countries, the physical and geometrical parameters are specified. In the USA there is no conveyor belt standard/norm.

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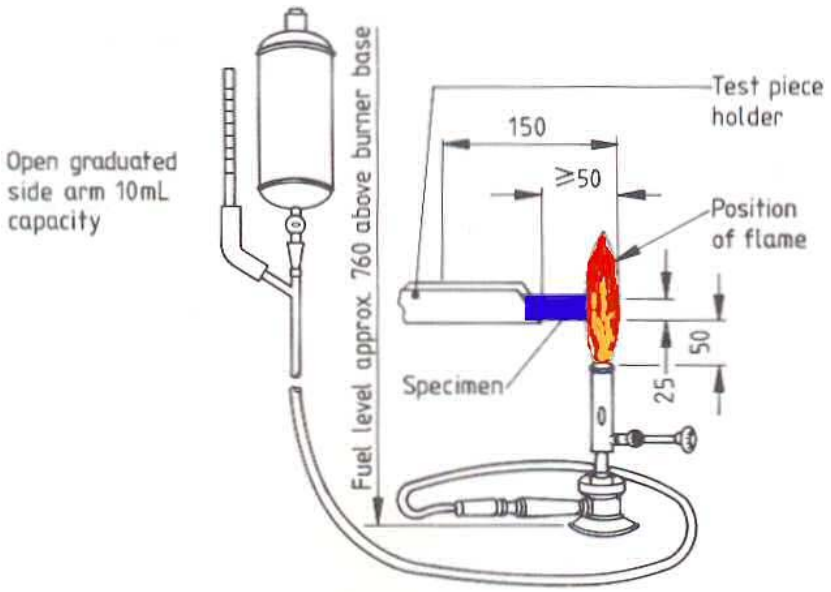
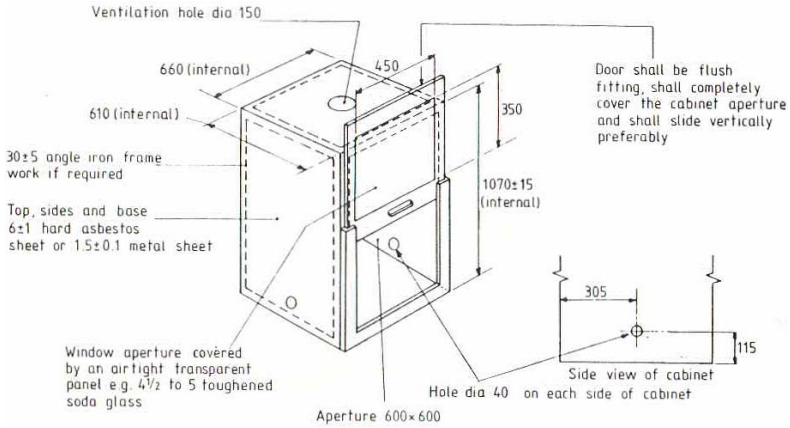
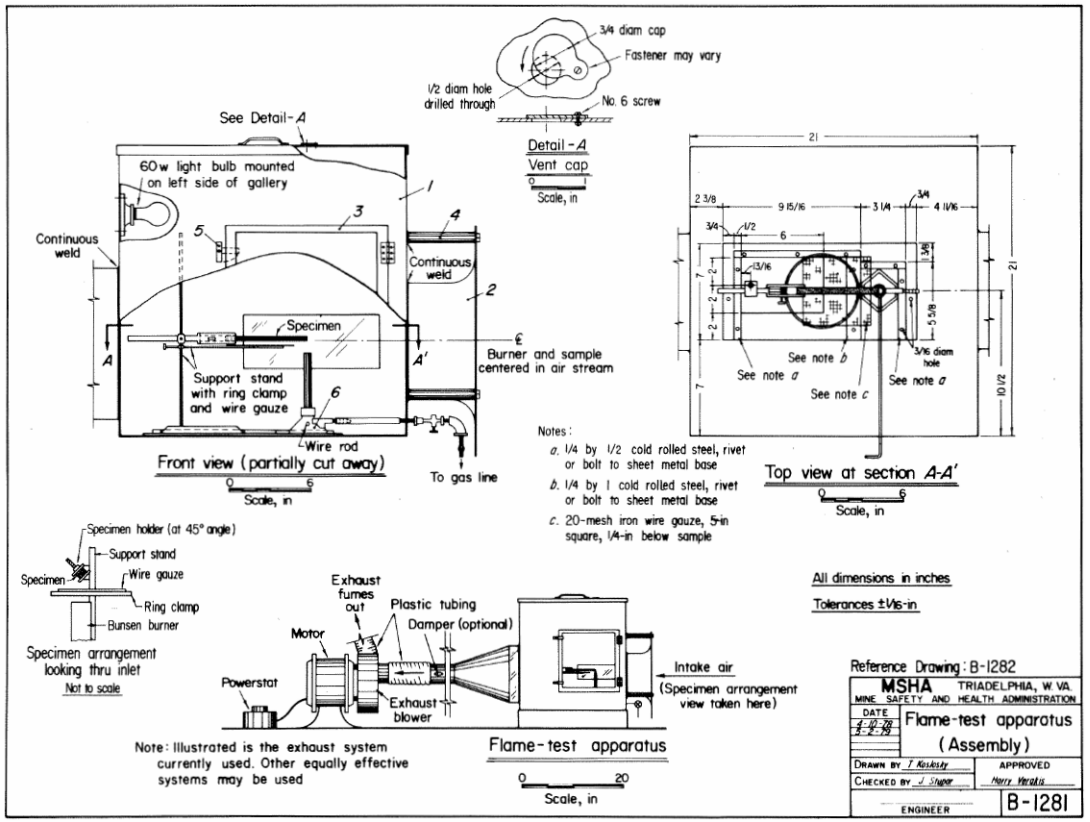
4.3 ISO340/DIN22103 and MSHA ASTP5007
Conveyor Belt Flammability Tests

PHOENIX Conveyor Belts







Sample sizes	
ISO/DIN:	200 x 25 mm
MSHA:	152 x 13 mm

A small piece of belt is held over a spirit/bunsen burner flame. After a certain time the burner is retracted and the duration of flames is recorded.

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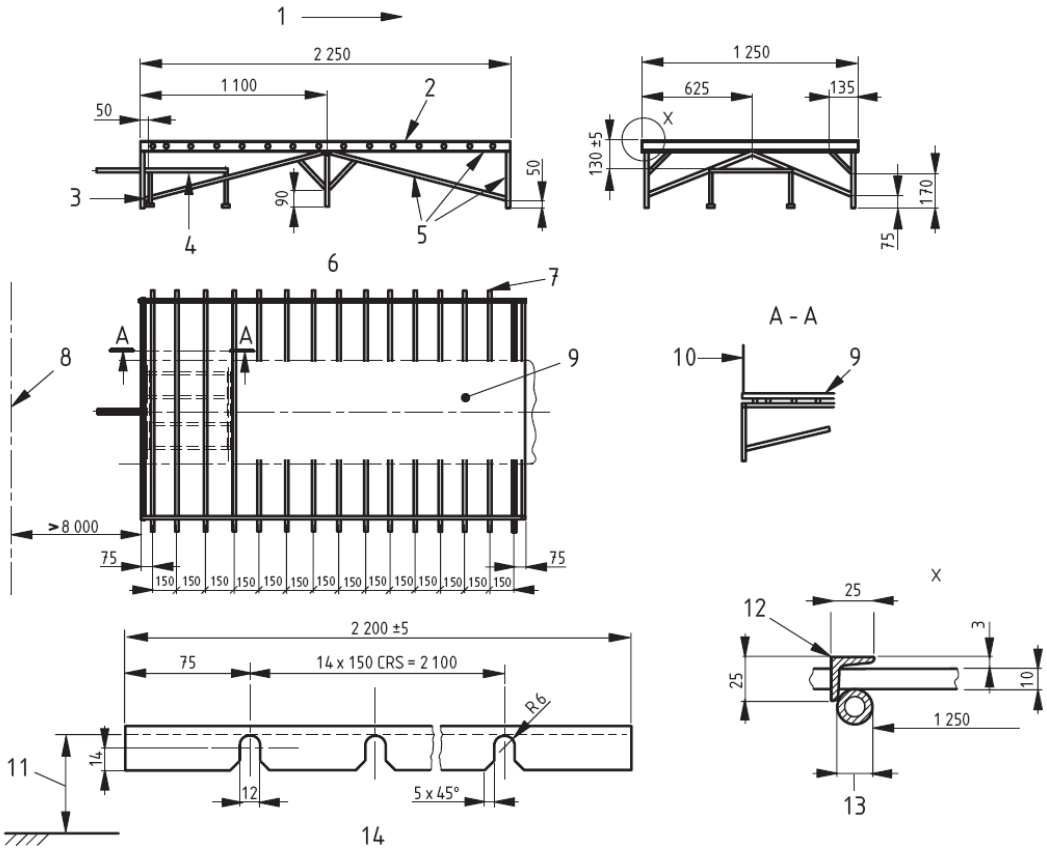
4.4 Propane Burner Test (EN 12881 et al.)

Conveyor belts must not propagate fire.
To test this, a belt specimen (1,5 - 2,5 m long x 1200 mm wide) is ignited by a propane burner. After the ignition source has been removed, the flames must self-extinguish and a defined undamaged length must remain.



Key

1 Direction of air flow
2 Additional bar
3 To be clear of any cross bracing
4 Propane burner
5 DN 15 heavy series tube
6 Detail of trestle
7 Bars made of austenitic chrome/nickel steel, diameter 10 mm, length 1,4 m
8 Gallery entrance
9 Test piece
10 Edge of test piece to be flush with front of trestle
11 350 mm to flow line
12 Rod retainers
13 DN 15 heavy series trestle
14 Detail of rod retaining angle

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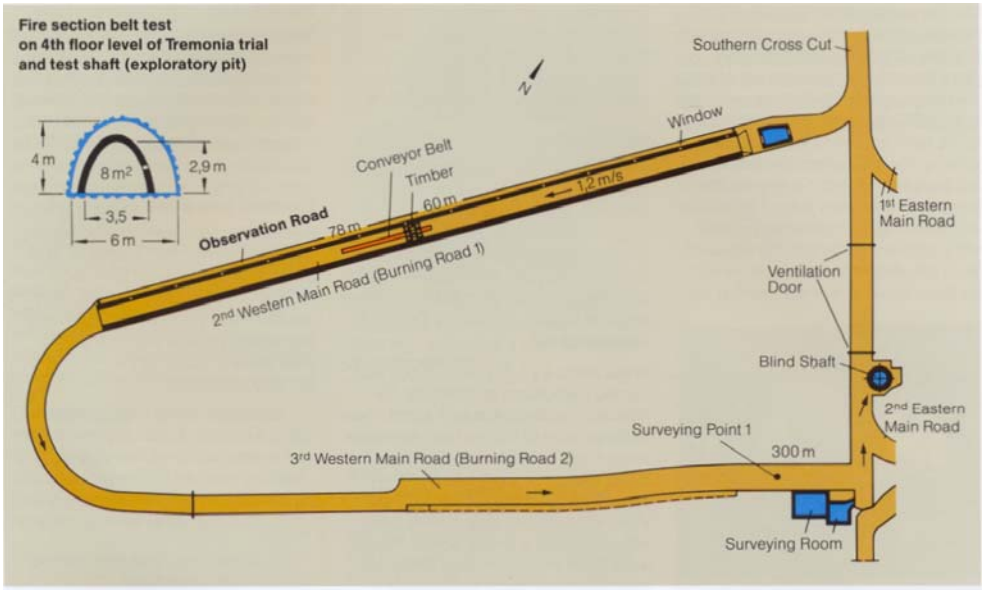
4.5 Large Scale Fire Test (EN 12881-2)



An 18 m long x full width belt specimen
is placed over 300 kg of timber
which is set on fire.
The maximum permissible flame spread is 10 m.


Test arrangement (model) before test
Fresh air side

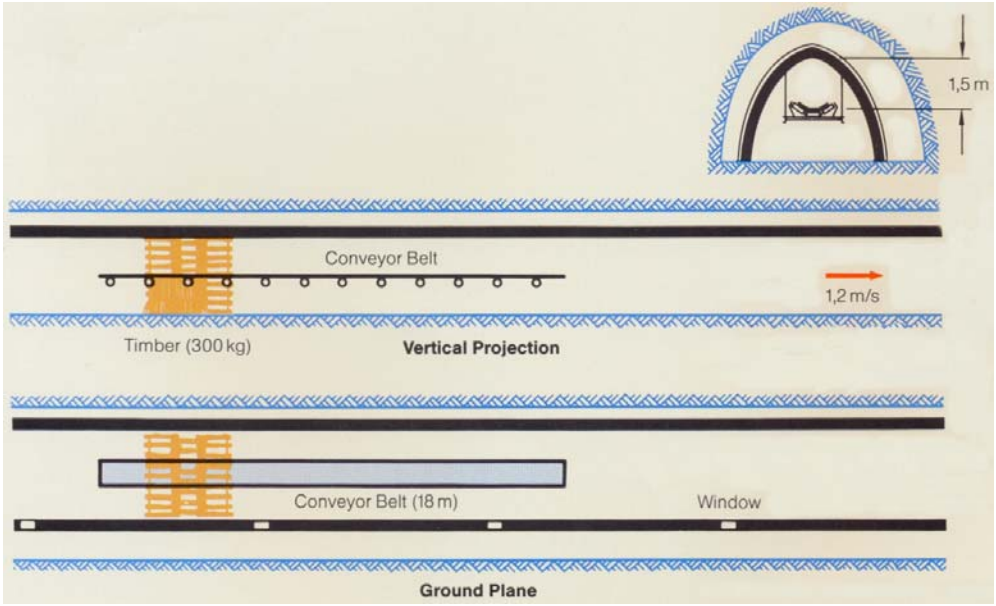

Test arrangement (model) before test
Waste air side


Test arrangement (model) after test
Fresh air side


Test arrangement (model) after test
Waste air side


Partly thermally damaged conveyor belt
After the test

Reference:
Illustrations by
Versuchsgruben-
gesellschaft mbH,
Dortmund, FRG



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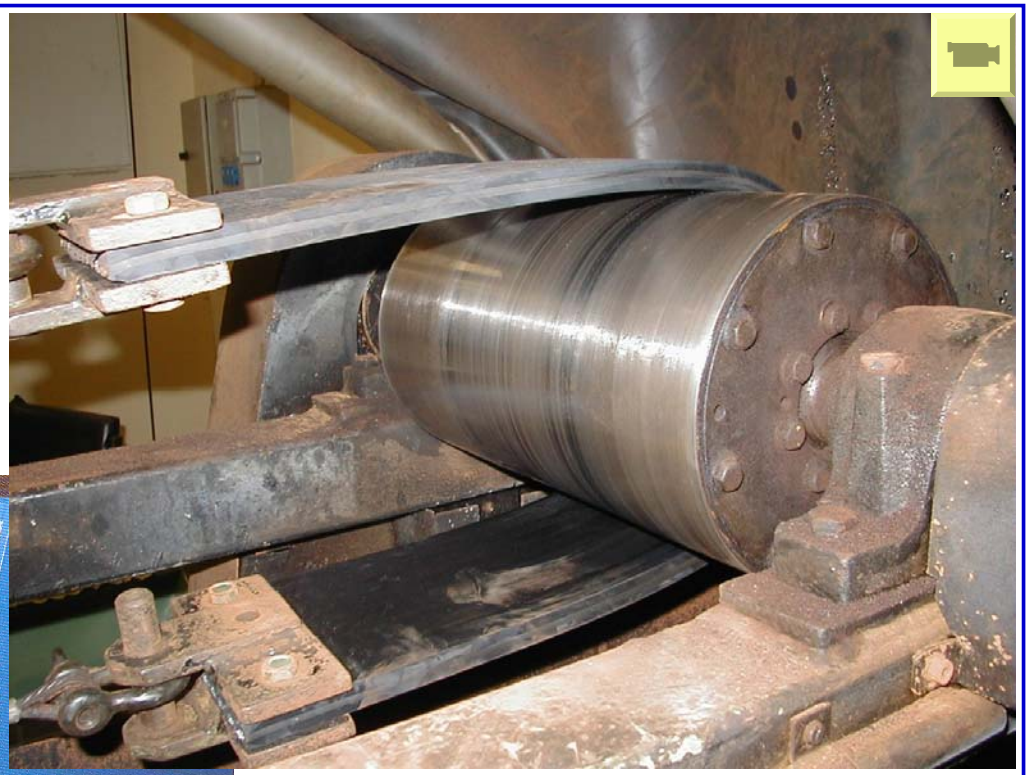
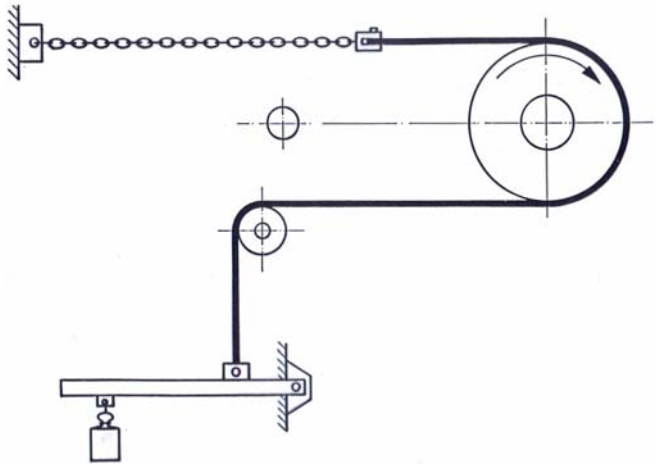
4.6 Drum Friction Test (DIN22100 et al.)

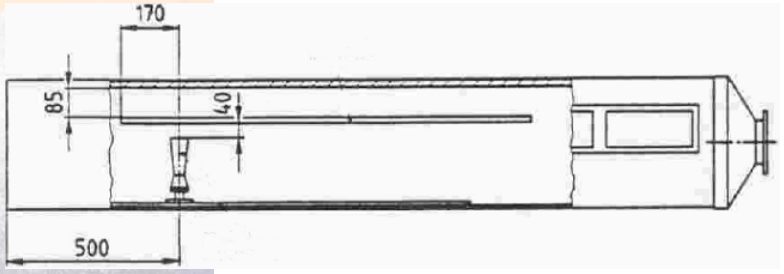
The test simulates a belt slipping over a jammed pulley or a pulley rotating under a stationary belt.

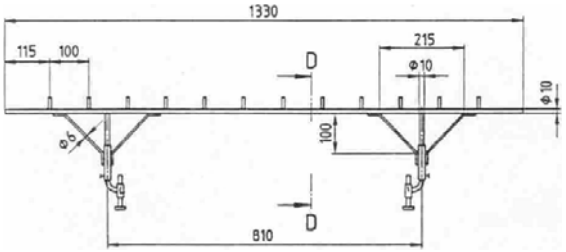
The surface temperature has to remain below 325°C and no flame or glow may be visible.





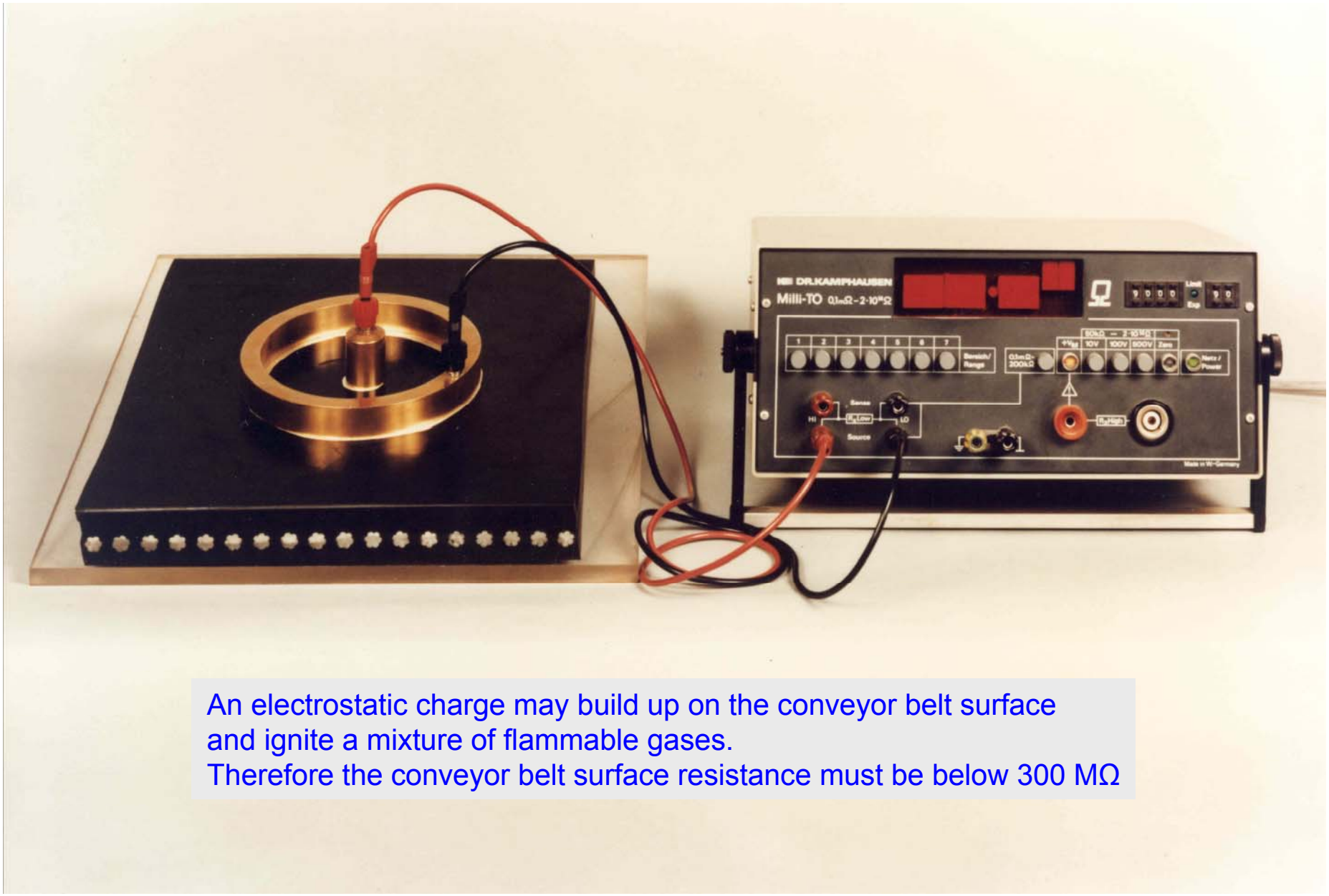
4.7 Laboratory Scale Gallery Test (DIN 22100 and 22118)





A 1200 mm long x 120 mm wide belt specimen is placed over a propane burner.
After the ignition source has been removed, the flames must self-extinguish
and a defined undamaged length must remain.

4.8 Surface Resistance Test (DIN 20284 et al.)



An electrostatic charge may build up on the conveyor belt surface
and ignite a mixture of flammable gases.
Therefore the conveyor belt surface resistance must be below 300 MΩ

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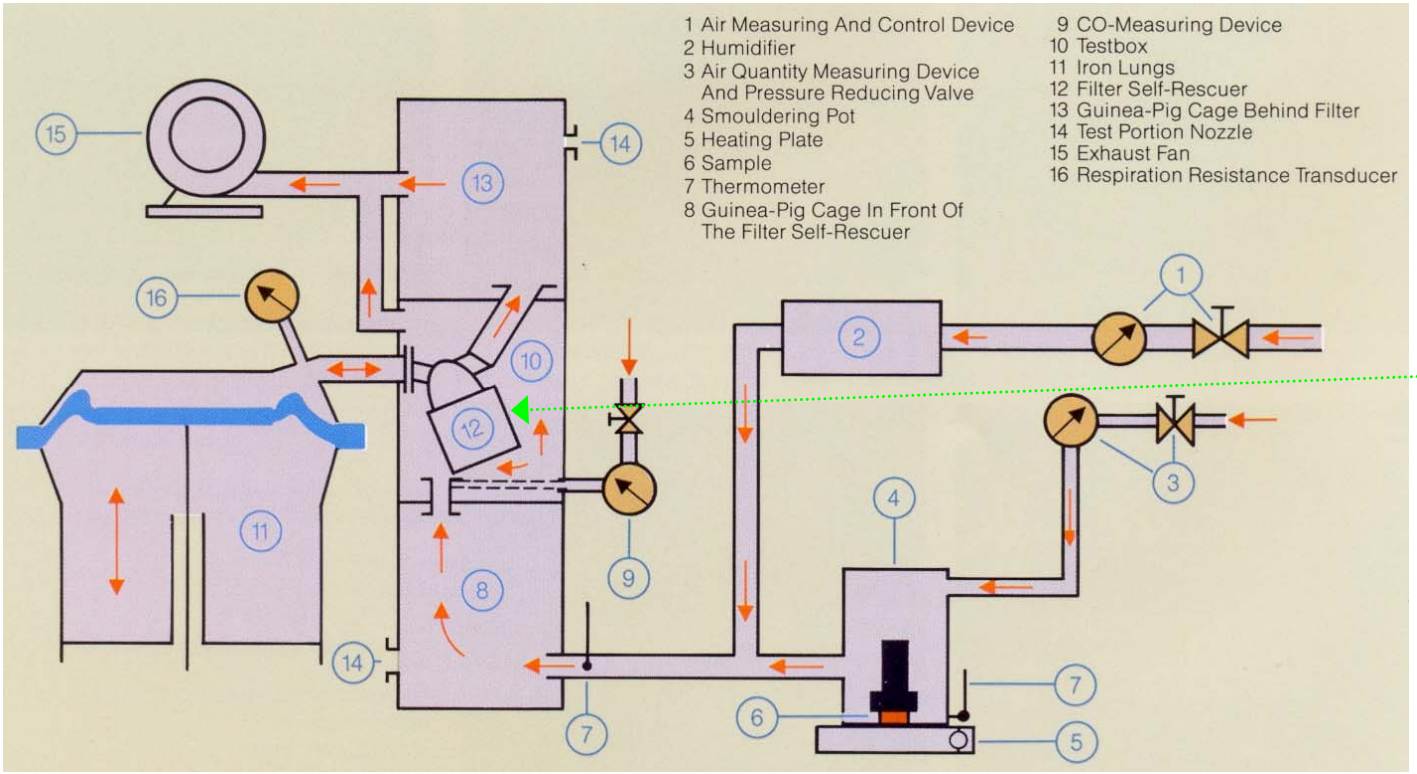
4.9 Hygienic Tests (DIN 22100)



Under normal operating conditions, conveyor belts must not put the health at risk.
Under the influence of heat or fire, belt decomposition substances must not cause irritation of the skin or eyes; the protective action of the filter self-rescuer must be kept.
DIN 22100 describes aerobic, chromatographic and pyrolytic hygiene tests, which have to be passed successfully.

In the smolder pot test, a belt sample is burned carbonized, then air and water vapour are added. This airflow must not increase the filter self-rescuer‘s airway resistance by more than 5 mbar.

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4.10 Fire Resistance Test Sample Sizes

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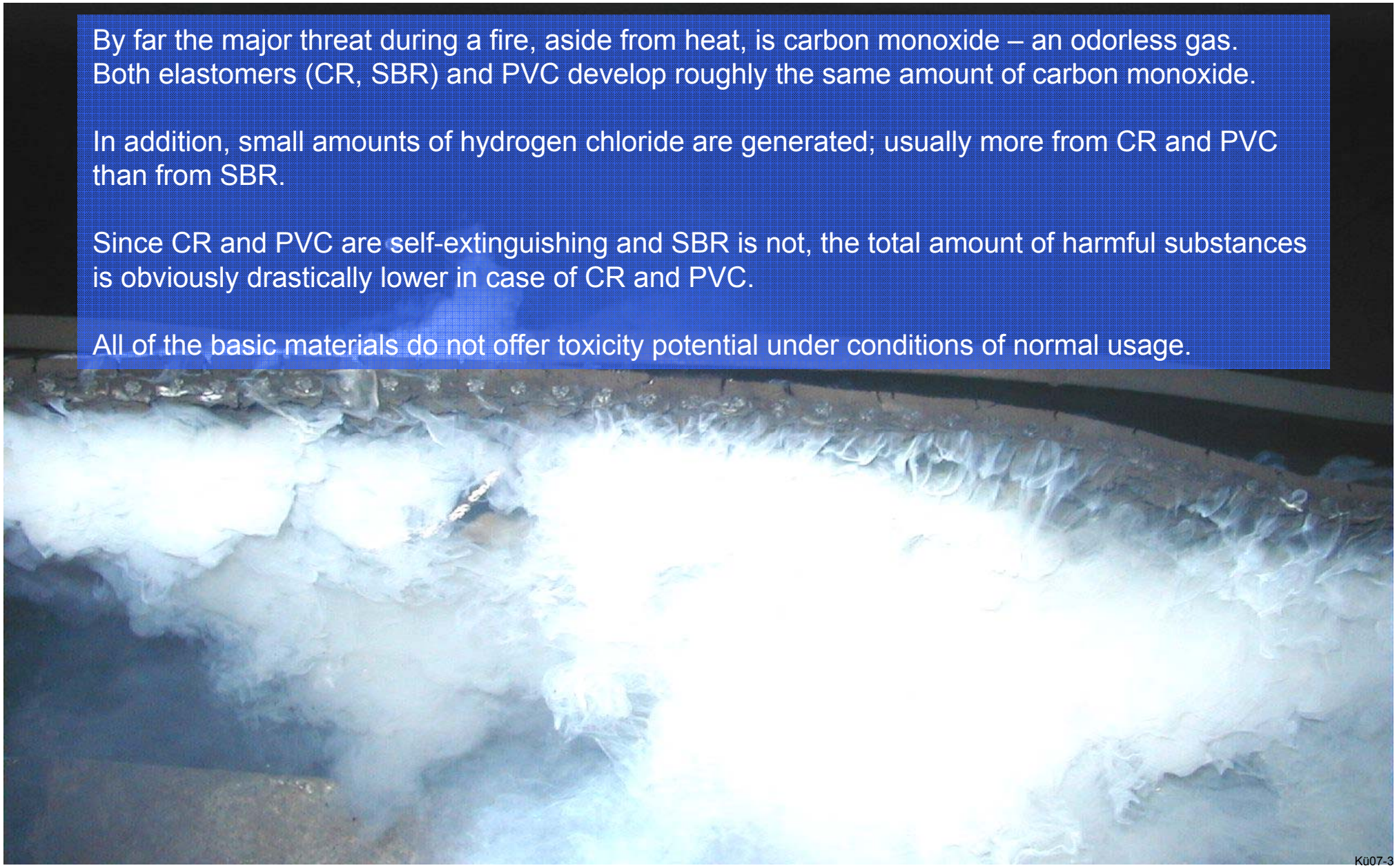
4.11 Toxicity Comparison



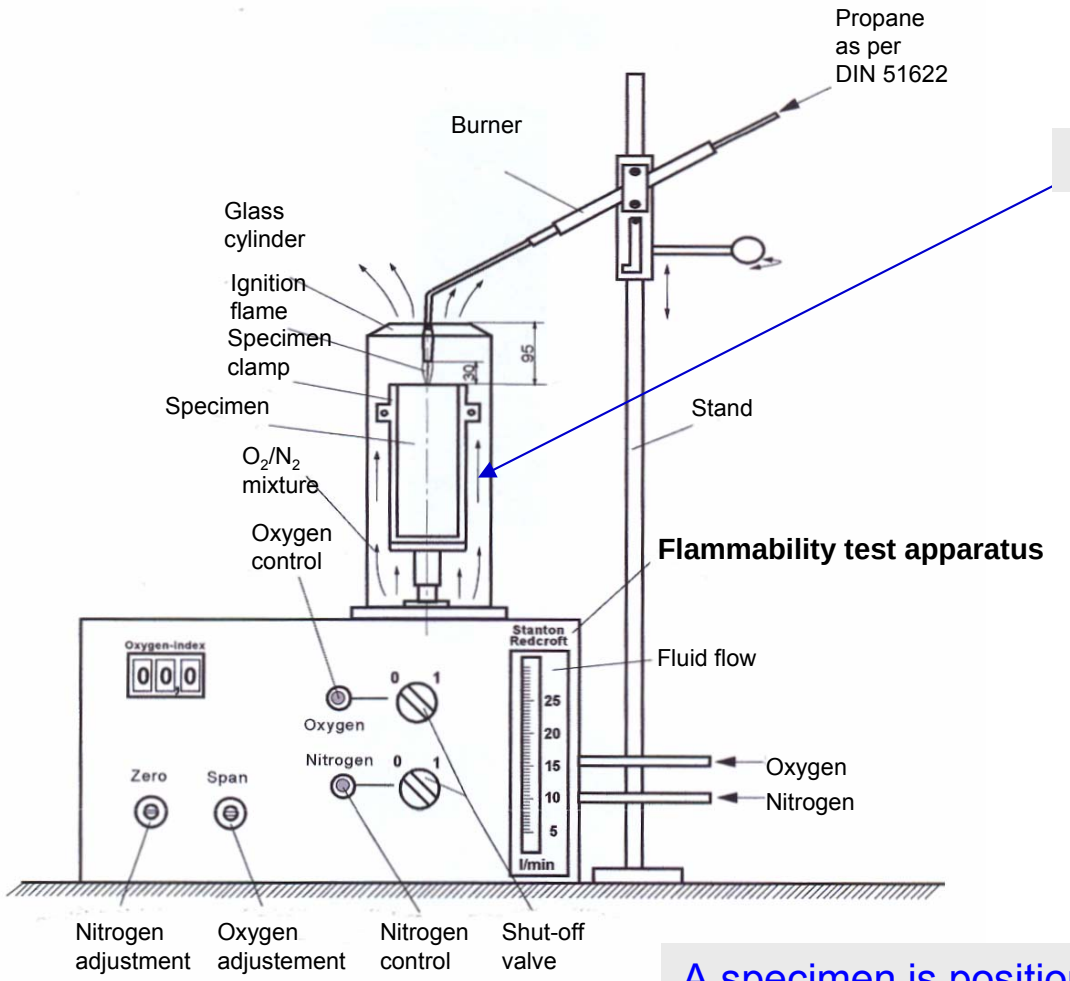
By far the major threat during a fire, aside from heat, is carbon monoxide – an odorless gas. Both elastomers (CR, SBR) and PVC develop roughly the same amount of carbon monoxide.

In addition, small amounts of hydrogen chloride are generated; usually more from CR and PVC than from SBR.

Since CR and PVC are self-extinguishing and SBR is not, the total amount of harmful substances is obviously drastically lower in case of CR and PVC.

All of the basic materials do not offer toxicity potential under conditions of normal usage.

4.12 Limiting Oxygen Index Test (ISO 4589 et al.)



Belt specimen (150 x 50 mm).

A specimen is positioned vertically in a transparent test column and a mixture of oxygen and nitrogen is forced upward through the column. The specimen is ignited at the top and the initiating flame is removed. The oxygen concentration is adjusted until the specimen just supports combustion. The concentration reported is the volume percent.

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4.13 Australian Test Certificate

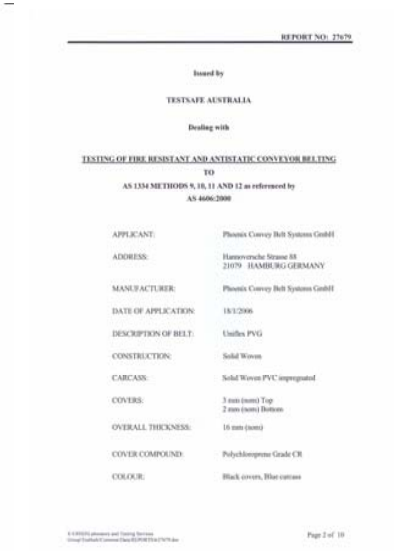
Test Safe
AUSTRALIA

REPORT

No:
Date of Issue:
File No:

Prepared for:
PHOENIX CONVEYOR BELT SYSTEMS GmbH

Type Testing of Uniflex PVG Solid Woven Belting to AS 4606:2000



REPORT NO: 27679

Issued by

TESTSAFE AUSTRALIA

Dealing with

TESTING OF FIRE RESISTANT AND ANTISTATIC CONVEYOR BELTING
TO
AS 1334 METHODS 9, 10, 11 AND 12 as referenced by
AS 4606:2000

APPLICANT:	Phoenix Convey Belt Systems GmbH
ADDRESS:	Hamerovsche Strasse 88 21079 HAMBURG GERMANY
MANUFACTURER:	Phoenix Convey Belt Systems GmbH
DATE OF APPLICATION:	18/1/2006
DESCRIPTION OF BELT:	Uniflex PVG
CONSTRUCTION:	Solid Woven
CARCASS:	Solid Woven PVC impregnated
COVERS:	3 mm (nom) Top 2 mm (nom) Bottom
OVERALL THICKNESS:	16 mm (nom)
COVER COMPOUND:	Polychloroprene Grade CR
COLOUR:	Black covers, Blue cutrass

REPORT NO: 27679

TEST SPECIFICATION: AS 1334.9-1982
AS 1334.10-1994 including additional test on samples without covers required by AS4606—2000
AS 1334.11-1988
AS 1334.12-1996

Acceptance Criteria as given in Section 7 of AS 4606—2000 *Fire resistant and antistatic requirements for conveyor belting used in underground coal mines*

OVERALL RESULT: Pass

REMARKS

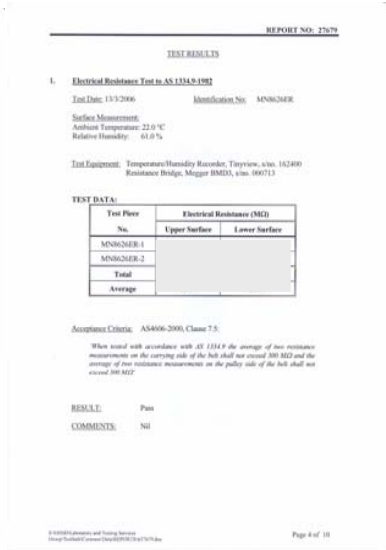
1. Please note that the test results contained in this report apply only to the sample of conveyor belting which was tested and may not be indicative of the total belting from which the sample was drawn.
2. Samples marked:
MN8626ER-1 and MN8626ER-2 used for the electrical resistance tests.
MN8626LF-1 to MN8626LF-10, and MN8626LF-1u to MN8626LF-10u used for laboratory flame tests.
MN8626DF-1 to MN8626DF-8 used for the drum friction tests.
MN8626GF-1 to MN8626GF-3 used for the gallery flame tests.
3. These test results on their own do not indicate the fire hazard of the belting under actual fire conditions and consequently, should not be applied to the assessment of fire hazard without taking into account additional supportive information.

Signatory (G. Gerisch)

NATA

Accreditation No. 1032

The tests, calibrations or measurements covered by this document have been performed in accordance with NATA requirements which include the requirements of ISO/IEC 17025 and are traceable to national standards of measurement. This document shall not be reproduced except in full.



REPORT NO: 27679

TEST RESULTS

1. **Electrical Resistance Test to AS 1334.9-1982**

Test Date: 13/3/2006 Identification No: MN8626ER

Surface Measurement:
Ambient Temperature: 22.0 °C
Relative Humidity: 61.0 %

Test Equipment: Temperature/Humidity Recorder, Tinyview, s/no. 162400
Resistance Bridge, Megger BMD3, s/no. 000713

TEST DATA:

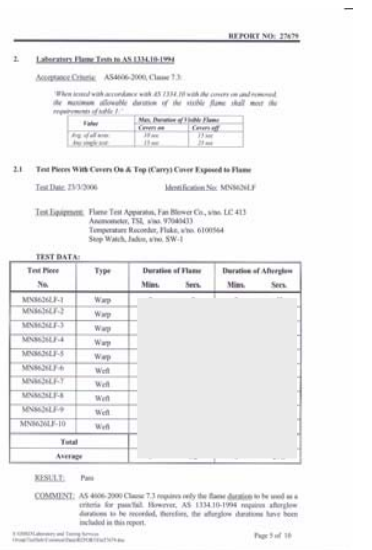
Test Piece No.	Electrical Resistance (MΩ)	
	Upper Surface	Lower Surface
MN8626ER-1		
MN8626ER-2		
Total		
Average		

Acceptance Criteria: AS4606-2000, Clause 7.5:

When tested with accordance with AS 1334.9 the average of two resistance measurements on the carrying side of the belt shall not exceed 300 MΩ and the average of two resistance measurements on the pulley side of the belt shall not exceed 300 MΩ

RESULT: Pass

COMMENTS: Nil



REPORT NO: 27679

2. **Laboratory Flame Tests to AS 1334.10-1994**

Acceptance Criteria: AS4606-2000, Clause 7.3:

When tested with accordance with AS 1334.10 with the covers on and removed, the maximum allowable duration of the visible flame shall meet the requirements of table 1:

Value	Max. Duration of Visible Flame	
	Covers on	Covers off
Avg. of all tests	10 sec	15 sec
Any single test	15 sec	25 sec

2.1 **Test Pieces With Covers On & Top (Carry) Cover Exposed to Flame**

Test Date: 23/3/2006 Identification No: MN8626LF

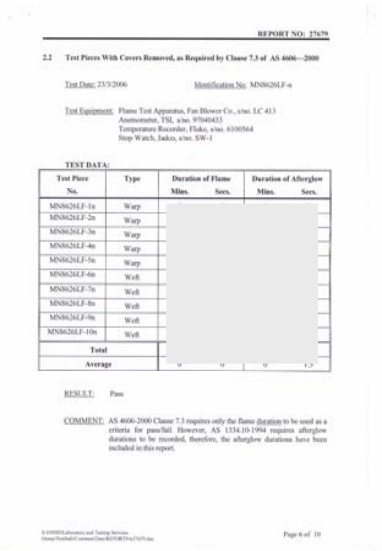
Test Equipment: Flame Test Apparatus, Fan Blower Co., s/no. LC 413
Anemometer, TSI, s/no. 97040433
Temperature Recorder, Fluke, s/no. 6100564
Stop Watch, Jadco, s/no. SW-1

TEST DATA:

Test Piece No.	Type	Duration of Flame		Duration of Afterglow	
		Mins.	Secs.	Mins.	Secs.
MN8626LF-1	Warp				
MN8626LF-2	Warp				
MN8626LF-3	Warp				
MN8626LF-4	Warp				
MN8626LF-5	Warp				
MN8626LF-6	Weft				
MN8626LF-7	Weft				
MN8626LF-8	Weft				
MN8626LF-9	Weft				
MN8626LF-10	Weft				
Total					
Average					

RESULT: Pass

COMMENT: AS 4606-2000 Clause 7.3 requires only the flame duration to be used as a criteria for pass/fail. However, AS 1334.10-1994 requires afterglow durations to be recorded, therefore, the afterglow durations have been included in this report.



REPORT NO: 27679

2.2 **Test Pieces With Covers Removed, as Required by Clause 7.3 of AS 4606—2000**

Test Date: 23/3/2006 Identification No: MN8626LF-u

Test Equipment: Flame Test Apparatus, Fan Blower Co., s/no. LC 413
Anemometer, TSI, s/no. 97040433
Temperature Recorder, Fluke, s/no. 6100564
Stop Watch, Jadco, s/no. SW-1

TEST DATA:

Test Piece No.	Type	Duration of Flame		Duration of Afterglow	
		Mins.	Secs.	Mins.	Secs.
MN8626LF-1u	Warp				
MN8626LF-2u	Warp				
MN8626LF-3u	Warp				
MN8626LF-4u	Warp				
MN8626LF-5u	Warp				
MN8626LF-6u	Weft				
MN8626LF-7u	Weft				
MN8626LF-8u	Weft				
MN8626LF-9u	Weft				
MN8626LF-10u	Weft				
Total					
Average					

RESULT: Pass

COMMENT: AS 4606-2000 Clause 7.3 requires only the flame duration to be used as a criteria for pass/fail. However, AS 1334.10-1994 requires afterglow durations to be recorded, therefore, the afterglow durations have been included in this report.

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3. **Drum Friction Test to AS 1334.11-1988**

Acceptance Criteria: AS4606-2000, Clause 7.2:

When tested with accordance with AS 1334.11, the surface temperature of the drum shall not exceed 325°C, and there shall be no visible flaming or visible glowing

Test Equipment: Drum Friction Machine, Penrith Engineering, s/no. LC 551
Chart Recorder, Yokogawa, s/no. 4HYN0043
Stop Watch, Jadco, s/no. SW-1
Anemometer, TSI, s/no. 97040433
Vernier, Mitutoyo, s/no. 0025652

TEST PIECE NO:	MN8626DF-1, 3mm Cover	TEST PIECE NO:	MN8626DF-2, 2mm Cover
AIRFLOW:	0 m/s	AIRFLOW:	0 m/s
TEST DATE:	10/3/200	TEST DATE:	22/3/2006

Elapsed time (mins)	Drum Temp °C	Flame or Glow	Elapsed time (mins)	Drum Temp °C	Flame or Glow

REPORT NO: 27679

TEST PIECE NO:	MN8626DF-3, 3mm Cover	TEST PIECE NO:	MN8626DF-4, 2mm Cover
AIRFLOW:	2.0 m/s	AIRFLOW:	2.0 m/s
TEST DATE:	22/3/2006	TEST DATE:	23/3/2006

Elapsed time (mins)	Drum Temp °C	Flame or Glow	Elapsed time (mins)	Drum Temp °C	Flame or Glow

TEST PIECE NO:	MN8626DF-5, 2mm Cover	TEST PIECE NO:	MN8626DF-6, 2mm Cover
AIRFLOW:	0 m/s	AIRFLOW:	0 m/s
TEST DATE:	23/3/2006	TEST DATE:	23/3/2006

Elapsed time (mins)	Drum Temp °C	Flame or Glow	Elapsed time (mins)	Drum Temp °C	Flame or Glow

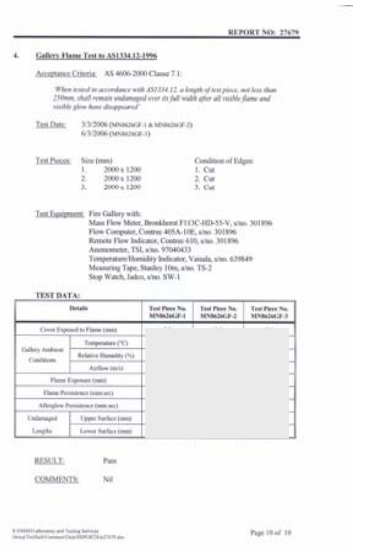
REPORT NO: 27679

TEST PIECE NO:	MN8626DF-3, 2mm Cover	TEST PIECE NO:	MN8626DF-4, 2mm Cover
AIRFLOW:	2.0 m/s	AIRFLOW:	2.0 m/s
TEST DATE:	24/3/2006	TEST DATE:	24/3/2006

Elapsed time (mins)	Drum Temp °C	Flame or Glow	Elapsed time (mins)	Drum Temp °C	Flame or Glow

RESULT: Pass

COMMENTS:
1. The maximum temperature recorded was 297.1 °C at the 3 minute and 00 second interval during the test on test piece MN8626DF-8



REPORT NO: 27679

4. **Gallery Flame Test to AS1334.12-1996**

Acceptance Criteria: AS 4606-2000 Clause 7.1:

When tested in accordance with AS1334.12, a length of test piece, not less than 250mm, shall remain undamaged over its full width after all visible flame and visible glow have disappeared

Test Date: 3/3/2006 (MN8626GF-1 & MN8626GF-2)
6/3/2006 (MN8626GF-3)

Test Pieces: Size (mm) Condition of Edges:
1. 2000 x 1200 1. Cut
2. 2000 x 1200 2. Cut
3. 2000 x 1200 3. Cut

Test Equipment: Fire Gallery with:
Mass Flow Meter, Bronkhorst F113C-HD-55-V, s/no. 301896
Flow Computer, Contros 405A-10E, s/no. 301896
Remote Flow Indicator, Contros 610, s/no. 301896
Anemometer, TSI, s/no. 97040433
Temperature/Humidity Indicator, Vaisala, s/no. 639849
Measuring Tape, Stanley 10m, s/no. TS-2
Stop Watch, Jadco, s/no. SW-1

TEST DATA:

Details		Test Piece No. MN8626GF-1	Test Piece No. MN8626GF-2	Test Piece No. MN8626GF-3
Cover Exposed to Flame (mm)				
Gallery Ambient Conditions	Temperature (°C)			
	Relative Humidity (%)			
	Airflow (m/s)			
Flame Exposure (min)				
Flame Persistence (mm/sec)				
Afterglow Persistence (mm/sec)				
Undamaged Lengths	Upper Surface (mm)			
	Lower Surface (mm)			

RESULT: Pass

COMMENTS: Nil

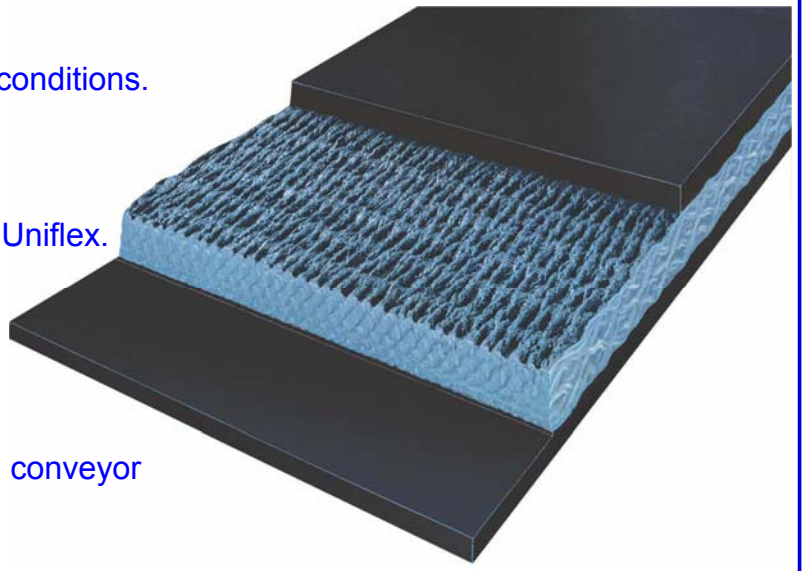
BK07-3

5.1 UNIFLEX vs. Multiply Conveyor Belts

UNIFLEX Conveyor Belts are the most modern type for underground coal mining.
They consist of a PVC impregnated solid woven carcass and chloroprene rubber covers.

- **Low Elongation**
Due to the very low elongation, Uniflex conveyor belts can be used on longer center distance conveyors with smaller take-ups.

- **Fatigue Strength**
Flex fatigue of both the splice and the carcass increases over time under operating conditions.
The fatigue strength of Uniflex belts is significantly higher.



- **Splice Strength**
The strengths of both vulcanized and mechanical splices are significantly higher for Uniflex.

- **UV Resistance**
Uniflex conveyor belts are resistant against ultraviolet light.

- **Edge Stability**
The Uniflex carcass is by design able to withstand considerarable contact force with conveyor structure, without tearing or separating as is experienced with multiply belts.

- **Wide Tension Range**
Belt breaking strengths are available from 330 to 1800 piw, allowing for longer centers and fewer drives on higher tension applications.

- **Safety**
The Uniflex carcass and covers are self-extinguishing, offering a higher degree of safety as per the strictest international requirements.

- **Impact and Rip Resistance**
The carcass is inherently more durable and abuse resistant. The impact and rip resistance of Uniflex belts are significantly higher.

Kü07-3

5.2 Comparison of Self-Extinguishing Textile Conveyor Belts

	PVC solid woven	CR multiply	PVG solid woven
Wear resistance	poor	good	excellent
Robustness, impact and rip resistance	good	good	excellent
Edge stability	good	poor	excellent
Suitability for belt-to-belt drives	poor	excellent	excellent
Suitability for man riding	poor	excellent	excellent
Tracking stability	good	excellent	excellent
Slope conveying	poor	excellent	excellent
Cleanliness (carry-over)	poor	excellent	excellent
Noise level	poor	excellent	excellent
Elongation properties	excellent	good	excellent

Kü07-3

5.3 Physical Properties of Cover Compounds

	SBR (USA)	CR (International)
Tensile strength	+	+
Elongation at break	+	++
Tear resistance	+	++
Abrasion resistance	+	+

Because of the negative effects of fire retarding chemicals in a SBR compound, the overall physical parameters deteriorate.

5.4 Cost Comparison

The prices for conveyor belts depend on the belt construction, the ingredients, the production facilities etc. etc.

As a rule of thumb, prices for self-extinguishing rubber conveyor belts will be 10 to 30 % higher than for flame retardant types.
Self-extinguishing PVC conveyor belts will be 10 to 20 % cheaper than flame retardant rubber belts.

The higher safety and the better operational performance easily compensate the additional costs for self-extinguishing rubber conveyor belts.

6. PHOENIX - MSHA

In 1996, PHOENIX provided the MSHA with samples of

- St 7500 Phoenocord steel cord conveyor belt and
- EP 3150/1 Uniflex textile conveyor belt

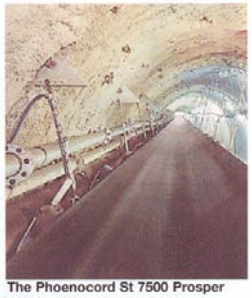
in self-extinguishing grade as per the German standard for underground conveyor belts resp. as per the then proposed new MSHA rules for the USA, free of charge.

PHOENIX will be pleased to assist the MSHA also in future.

Additional Literature

The success story of self-extinguishing steel cord conveyor belts in underground coal mining

In 1975, the German mining authorities implemented stricter requirements for conveyor belts for use in underground coal mines. All existing flame resistant underground steel-cord conveyor belts had to be replaced within a specified time with so-called self-extinguishing types as per DIN standard 22129. This article describes the performance of such high strength steel cord conveyor belts



The Phoenocord St 7500 Prosper Haniel slope conveyor belt

The first self-extinguishing steel cord conveyor belt at Göttelborn mine in Germany

The world's first self-extinguishing steel cord conveyor belt was a 3,000m long and 1,400mm wide type Phoenocord St 4000. It wa commissioned in 1976, in Saarberg's Göttelborn underground mine in south west Germany.

The 28mm thick conveyor belt with Phoenotec synthetic single cord reinforcement is operating on a slope conveyor with a lift of 300m.

After 12 years of operation a length including a splice was taken from this belt for comprehensive testing. The overall results were excellent: the fire behaviour was unchanged and the technical data were within the requirements for the new conveyor belt.

In 1993, after 16 years of operation and 44mt of conveyed coal, the same procedure was repeated. Again, the test results were within the original range. The rubber cover wear was a mere 1-2mm.

The latest "birthdays"

A 3,800m long and 1,400m wide conveyor belt type Phoenocord St 4500 with 10 plus 8mm covers,

The Phoenocord St 7500 splice, 6,750mm long

including Phoenotec reinforcements, is carrying coal over a conveying lift of 349m in the so-called Barbarastollen. It was commissioned in January 1978 at Saarberg's Ensdorf mine. Ensdorf produces approximately 2.5mt of coal per year. After 20 years and 70mt of conveyed raw coal the conveyor belt and all of its original splices are still in operation.

In January 1979, 300m of 1,200mm wide Phoenocord St 5000 were commissioned at Ruhrkohle's Friedrich Heinrich mine. This belt conveys raw coal over a lift of 390m. Still the Phoenocord conveyor belt including all its original splices is in good condition. No standstill caused by either of the conveyor belts or their splices has ever occurred.

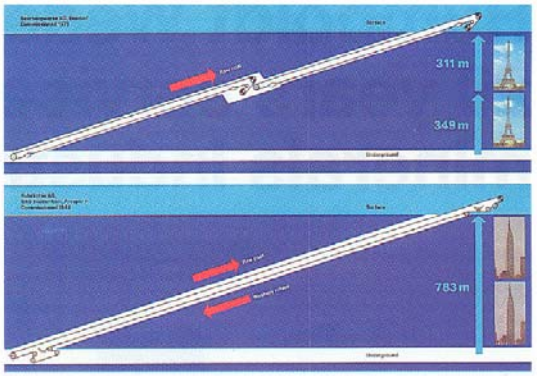
The strongest one

The strongest conveyor belt on earth is a Phoenocord St 7500 operating at Ruhrkohle's Prosper Haniel mine. The actual conveyor belt strength is 8,200 N/mm. The diameter of the 72 steel cords is 12.5mm giving an elastic modulus of 500kN/mm. The belt has 10 plus 12mm thick rubber covers including Phoenotec protection system. Its width is 1,400mm.

The stringent safety requirements were passed by the belt with excellent results. A dynamic splice fatigue strength as per DIN 22110/P3 of 38 per cent was achieved, which was the "world record". The 21 6,750mm long splices are the longest in the world.

This unique super belt conveys 1,800t/h raw coal over a distance of 3,745m from a depth of 783m underground to the surface at a speed of 5.5m/s. At the same time, 1,000t/h washery refuse is conveyed back underground on the bottom run.

The belt was put into operation in November 1986. After 13 years of operation and 85mt conveyed material it is still in good condition.



Side view of the slope conveyors at Ensdorf and Prosper Haniel mines in Germany

Conveyor belt construction

A Phoenocord conveyor belt based on DIN 22129 is a complex construction consisting of:

- Open stranded fire-zinc coated steel cords;
- Polychloroprene rubber based wearing covers;
- Special core adhesion rubber;
- Single synthetic cord transverse reinforcement.

Drive data of Phoenocord St 7500

Drive layout	1 head pulley
Pulley diameter	2,200mm
Installed motor power	2x3,100kW
Type of motor	3-phase current synchronous
Rated moment	631kNm
Max start-up torque	820kNm
Rotor weight	20t
Stator weight	25.5t
Shaft diameter	900mm

The conveyor belt must have the greatest possible wear and damage resistant properties in addition to having the inherent characteristics of resisting the influence of mine water and other operating hazards, thus maintaining its initial safety and performance standards.

All material – elastomers and polymers – must have adequate fatigue strength, ie high resistance to ageing. Polychloroprene rubber (CR) – as one of the main ingredients in self-extinguishing steel cord conveyor belts – offers a priori fire safety advantages and high resistance to ageing. In case of the formerly used flame resistant grades which were based on styrolbutadien rubber (SBR), fire retardants had to be added.

The weakest point in a conveyor belt is the joint. The field splices must achieve the same surface life as the belt itself. They must also be in compliance with the underground safety requirements. All of the high-strength steel cord conveyor belts in German underground mining were made under Phoenix supervision, with Phoenix splicing material, based on patented Phoenix splicing designs. Extensive development, testing and practical experience have made this success possible.

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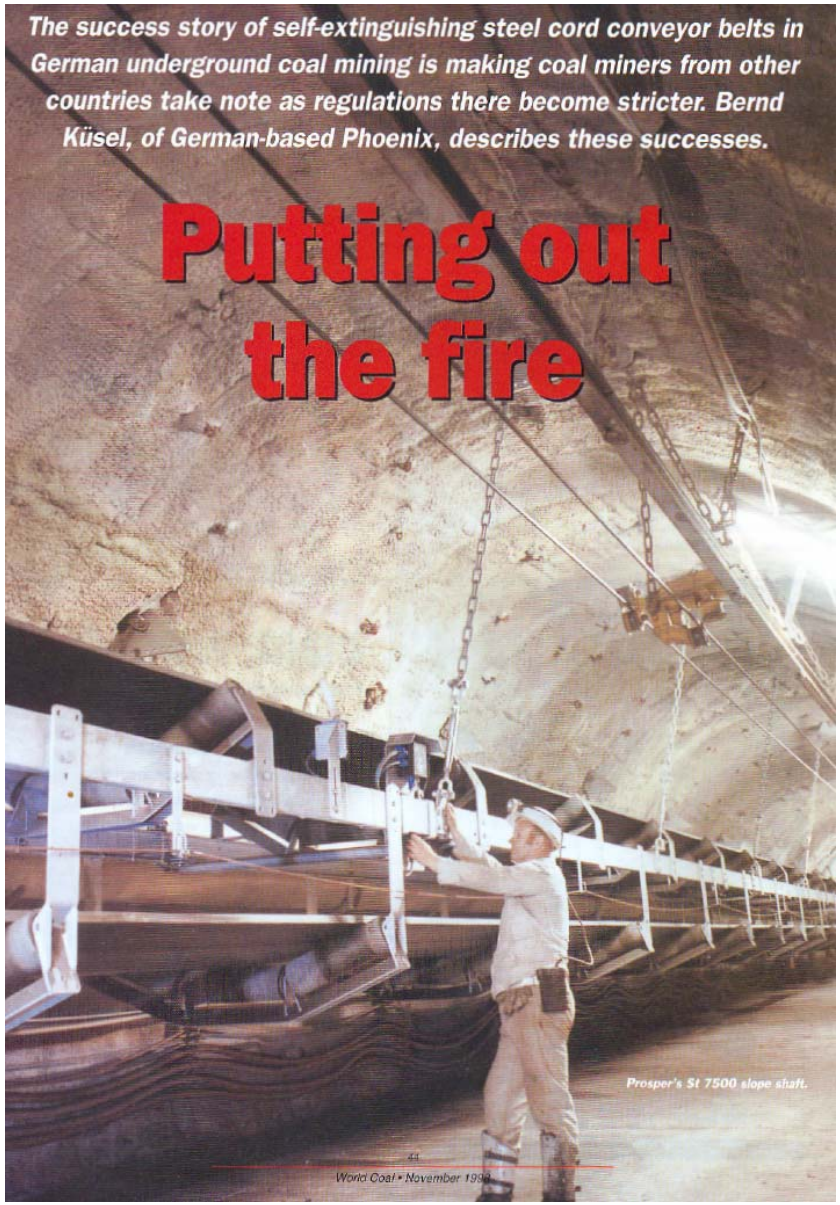
Putting out the fire - *World Coal Magazine*



The success story of self-extinguishing steel cord conveyor belts in German underground coal mining is making coal miners from other countries take note as regulations there become stricter. Bernd Küsel, of German-based Phoenix, describes these successes.

Putting out the fire

Prosper's St 7500 slope shaft.

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World Coal • November 1998

CONVEYOR SPOTLIGHT

Between 1960 and 1972, 831 conveyor belt related fires were recorded in West Germany. As a result, the German mining authorities condemned the use of the conveyor belts used in the mines, which were designed to be fire resistant and anti-static. These belts, which were designed to German Industry Standards (DIN) at the time, were believed to actually aid the spread of fire over long distances.

Consequently, in 1975 the German mining authorities implemented new requirements for steel cord conveyor belts (DIN 22109). These new regulations demanded that the new conveyors were subjected to the most stringent tests. These included:

- A specially prepared 2m long sample is exposed to the flames of a large propane burner. After the test, a part of the belt sample has to be intact across the whole width.
- An 10m long full belt width sample is tested in a real underground fire environment and the belt must not be burning 10m away from the the fire.
- During the fire, fumes must be minimal and the inhaling resistance of a filter self-rescuer must not increase by more that 5bar during the smoulder pot test.
- The surface resistance must be at least 3x 10^9Ω.
- The lowest oxygen index which is used as a method of identifying a conveyor belt's fire behaviour (DIN 22107).

With these regulations in place all the existing underground steel-cord conveyor belts had to be replaced within a specified time with the new so-called self-extinguishing types (DIN 22129).

This article describes the performance of such high strength steel cord conveyor belts to-date.

Prosper's St 7500 conveyor drive station.

The first one

The world's first self-extinguishing steel cord conveyor belt was 3000m long and 1400mm wide, type Phoenocord St 4000. It was commissioned in 1976 in Saarberg's Göttelborn underground mine in South West Germany. Göttelborn produces approximately 2Mt of hard coking coal per year.

The 28mm thick conveyor belt with Phoenotec synthetic single cord reinforcement is operating on a slope conveyor with a lift of 300m. After 12 years of operation, a length including a splice was taken from this belt for comprehensive testing. The overall results were excellent: the fire behaviour was unchanged and the technical data was within the requirements for the new conveyor belt.

In 1983, after 16 years of operation and 44Mt of conveyed coal, the same procedure was repeated. Again, the test results were within the original range. The rubber cover wear was a mere 1.2mm.

The others

In the period between 1979 and 1985, three 3000KN/m belts went into service in coal mines using slope conveyors with lifts varying from 200 to 400m.

A 3600m long and 1400mm wide conveyor belt, the Phoenocord St 4500 with 10mm plus 5mm covers including Phoenotec reinforcements, carries coal over a conveying lift of 349m in the so-called Barbarastollen. It was commissioned in January 1978 at Saarberg's Ensdorf mine which produces around 2.5Mtns of hard coking coal. After 20 years the conveyor belt and all of its original splices are still in operation.

In January 1979, 3300m of 1200mm wide Phoenocord St 5000 was commissioned at Ruhrkohle's Friedrich Heinrich mine, which produces over 3.5Mtns of coking coal. This belt conveys run-of-mine coal over a lift of 300m. The Phoenocord conveyor belt including all its original splices is still in good condition. No downtime caused by problems with either the conveyor belts or their splices has ever occurred.

The strongest one

The strongest conveyor belt on earth is a Phoenocord St 7500 operating at Ruhrkohle's Prosper Haniel mine. The actual conveyor belt strength is 8200N/mm. The diameter of the 72 steel cords is 12.5mm giving an elastic modulus of 5003N/mm.

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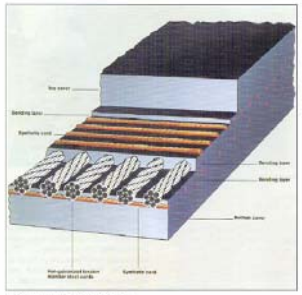
World Coal • November 1998

The first self-extinguishing steel cord conveyor belt.



Steel cord conveyor belt construction.

The belt has 10mm plus 5.2mm thick rubber covers including Phoenotec protection system. Its width is 1400 mm.

A dynamic splice fatigue strength (as per DIN 22110/7) of 30 per cent was achieved, which was the "world record" and the 21 670mm long splices are the longest in the world. This unique superbelt conveys 1500tph of run-of-mine coal over a distance of 3740m from a depth of 780m underground to the surface at a speed of 5.5m/s. At the same time, 1000tph of roadway refuse is conveyed back underground on the conveyor's bottom run.

The belt went into operation in November 1996. After 15 years of operation and many millions of tonnes conveyed it is still in good condition.

CONVEYOR SPOTLIGHT

To drive such a large conveyor belt obviously requires an extremely powerful drive. The drive's mechanical attributes are outlined below:

Drive layout	1 head pulley
Pulley diameter	2.500 mm
Installed motor power	2 x 1100kW
Type of motor	3-phase current synchronous
Rated moment	631kNm
Maximum start-up torque	820 kNm
Rotor weight	20t
Stator weight	25.5t
Shaft diameter	900mm

Conveyor belt construction

A Phoenocord conveyor belt based on DIN 22129 is a complex construction consisting of:

- open stranded fire-zinc coated steel cords
- polychloroprene rubber based wearing covers
- special cow adhesion rubber
- single synthetic cord transverse reinforcement

The conveyor belt must have the greatest possible wear and damage resistant properties, in addition to having the inherent characteristics of resisting the influence of mine water and other operating hazards, thus maintaining other safety and performance standards.

All material – elastomers and polymers – must have adequate fatigue strength. Polychloroprene rubber (CR), as one of the main ingredients in self-extinguishing steel cord conveyor belts, offers fire safety advantages and a high resistance to ageing. In the case of the formerly used flame resistant grades, which were based on styrol-butadien rubber (SBR), fire retardants had to be added.

The weakest point in a conveyor belt is the joint. The field splices must achieve the same service life as the belt itself. For this reason all of the high-strength steel cord conveyor belts in German underground mining were made under Phoenix supervision, with Phoenix splicing material or using Phoenix splice designs.

More than 20 years of practical performance of the conveyor belts, and their splices show that it was a good decision by the German mining authorities to implement the present strict requirements. With mining regulations becoming stricter in many other countries Phoenix is well placed to provide a solution to the problems that this will bring.

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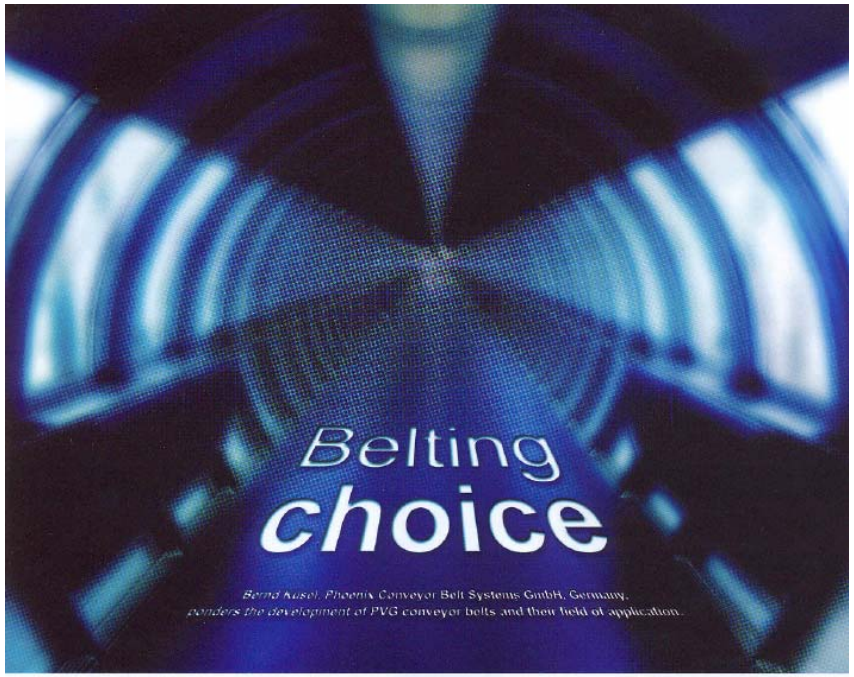
World Coal • November 1998

Kü07-3

Belting Choice - *World Coal Magazine*

PHOENIX Conveyor Belts



PVG conveyor belts have proven their outstanding reliability and efficiency in the last 25 years. This revolutionary conveyor belt construction consists of PVC impregnated solid woven fabric and rubber covers.

Development

In 2002, world coal production was at 3837 million t. Last year the figure was even higher, mainly because of an impressive growth in China from 1400 to 1600 million t.

Globally, the share of underground coal mining will reach 70% of all mined coal in a couple of years. In the two biggest coal producing countries, China and the US, the share is already above this figure.

On the tide of increasing mechanisation of underground coal haulage, belt conveyors are becoming more and more the indispensable choice due to their reliability and economy.

The operating conditions in underground mining are rough and require sturdy equipment. Conveyor belts are especially subjected to extreme strains from impact, stuck material, friction and component misalignment, etc.

In order to drastically improve the performance of underground conveyor belts, the uniflex PVG conveyor belt was developed. This consists of PVC, rubber and fabric.

The positive features of PVC solid woven conveyor belts include their low elongation, the high mechanical fastener retention, the avoidance of ply separation and the possibility of using smaller pulley diameters. Disadvantageous, however, is their low wear resistance and slippery surface. Rubber conveyor belts feature high wear resistance, high traction and poor sensitivity to temperature.

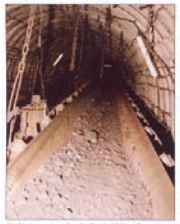
Thus the logical but very ambitious task was to combine the advantages of PVC and of rubber conveyor belts, in spite of their opposing characteristics. PVC is an amorphous thermoplastic made by polymerisation, linking the chains of the monomer vinyl chloride. Unlike rubber, polyvinylchloride melts or flows when heated.

Rubber can be stretched easily and is almost completely reversible, to high extensions. This is due to the irreversible process of vulcanisation, which crosslinks the molecules. To achieve this, the raw rubber is mechanically mixed with a number of compounding ingredients like fillers, anti-degradants, accelerators, etc., and then cured.

In 1978, after extensive research and development work with a particular focus on the dynamic and thermal stability, Phoenix realised the durable combination of the PVC and rubber components.

Strictest safety tests for the use in underground coal mines were passed then and the worldwide first approval was attained in mid-1979 from the German mining authorities.

For most countries in the world, polychloroprene rubber (CR, Neoprene) covers are required to pass the safety tests.



Coal being conveyed at the Ensdorf Mine, Germany.

Figure 1. A PVC impregnated solid woven carcass with rubber covers.

Figure 2. Diagram of multiple curing presses creating finger splices.

In Germany, this grade is called V or self-extinguishing. In the US, styrene/butadiene rubber (SBR) based covers with fire resistance additives are sufficient to pass the present MSHA tests. The uniflex PVG conveyor belts are available in both versions. Figure 1 shows the PVC impregnated solid woven carcass and the rubber covers.

Programme

In 1979 Phoenix commissioned the first conveyor belt of this design in a German hard coal mine. It had a minimum breaking strength of 2000 N/mm of belt width, with 4 mm rubber covers on the carrying side and 3 mm on the running side.

The supply programme was then completed with strength types of 600 - 1600 N/mm.

In 1992 type 3150/1 was added to the family. This is the strongest solid woven conveyor belt worldwide and 5280 m of it were installed in a coal mine in southwest Germany that year. Table 1 shows some parameters of the types as approved in Europe.

Practical application

During 25 years of practical application, Uniflex PVG conveyor belts have proven to have robustness and longevity. The quality parameters of the rubber covers correspond to the extremely high data level known from steel cord conveyor belts.

There are a number of examples that highlight a cross-section of applications in Europe. On one of the longest conveyors, with a centre distance of 4148 m and a troughing angle of 40°, a conveyor belt type 1200/EPBPB 2000/1 - 6+3 V is operating at a speed of 2.5 m/s, moving 2000 tph of ROM coal. The belt is driven by three 250 kW motors.

The designation 1200/EPBPB 2000/1 - 6+3 V stands for 1200 mm belt width, one PVC impregnated polyester (E) and polyamide (P) carcass with cotton (B) protection, a minimum belt breaking strength of 2000 N/mm, and 6 mm top plus 3 mm bottom rubber covers, grade V.

A conveyor transporting coal uphill.

On an uphill conveyor with a length of 1300 m, a troughing angle of 35°, and a speed of 2.5 m/s, conveying 2000 tph of coal, a conveyor belt type 1200/EPBPB 1800/1 - 6+6 V is operating. The belt is driven by four 160 kW motors.

One of the most interesting applications has a centre distance of 1314 m and a troughing angle of 60°.

The conveyor belt type is 1400/EPBPB 3150/1 - 6+3 V, powered by four 350 kW motors. It carries up to 2600 tph uphill at a speed of 3 m/s in the Fraschet underground mine in southwest Germany.

The splice of this belt has 3800 mm long hot vulcanised 'fingers', providing a dynamic splice efficiency of 35% as per DIN 22110. The belt weighs approximately 50 kg/m.

The same conveyor belt type is working on a 780 m long uphill system with a troughing angle of 40° and a speed of 3 m/s. Four 400 kW motors convey 2400 tph.

Table 1. Conveyor belt types approved in Europe

Belt type	600	1000	1000	1250	1250	1250	1600	2000	2500	3150
Breaking strength of the conveyor belt (N/mm min)	600	1000	1000	1250	1250	1250	1600	2000	2500	3150
Mechanical fastener insertion (N/mm) min	700	750	780	900	900	900	1000	1800	1200	1300
Permanent dynamic elongation (maximum %)	0.8	1.0	1.0	1.2	1.2	1.2	1.6	1.8	1.2	1.2
Elastic dynamic elongation (minimum %)	0.4	0.4	0.4	0.4	0.4	0.4	0.6	0.6	0.5	0.5
Belt thickness (mm, tolerance ± 1.5)	11.5	12.0	14.0	14.0	16.0	17.0	16.0	20.0	22.0	26.0
Cover thickness (mm, tolerance + 1/- 0.5)	2 + 2	2 + 2	3 + 3	2.5 + 2.5	3 + 3	4 + 4	3 + 3	3.5 + 3.5	4 + 4	6 + 3
Belt mass (kg/m², tolerance ± 2.2)	14.5	17.0	20.0	22.0	23.5	26.5	26.0	34.5	33.5	36.0

Table 2. Typical installations for Uniflex PVG conveyor belts in underground coal mines

Conveyor data						
Centre distance	m	4148	1500	1310	780	350
Capacity	tph	2000	2000	2800	2400	2000
Speed	m/s	2.5	2.5	3	3	3.5
Troughability		10°	35°	40°	40°	40°
Motor power	kW	3 x 250	4 x 160	4 x 350	4 x 400	5 x 160
Slope		horizontal	uphill	uphill	uphill	downhill
Belt data						
Width	mm	1200	1200	1400	1400	1200
Type		EPBPB 2000/1	EPBPB 1800/1	EPBPB 3150/1	EPBPB 3150/1	EPBPB 2000/1
Minimum breaking strength	N/mm	2000	1800	3150	3150	2000
Cover thickness	mm	6 + 3	6 + 6	6 + 3	6 + 3	6 + 3

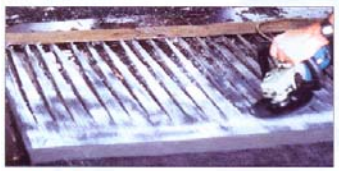


Figure 3. Three stages of splice preparation.

Another Uniflex PVG conveyor belt working at a relatively high speed of type 1200 / EPBPB 2000/1 - 6+3 V is 3.5 m/s. The centre distance is 350 m and the troughing angle is 40°. Five 160 kW motors are installed to haul 2000 tph downhill.

Differences between belt designs

The benefits of PVC conveyor belts include excellent wear resistance and robustness. The PVC impregnation minimises the elongation of the solid woven carcass. Solid woven means that a number of plies consisting of polyamide, polyester and cotton threads are interwoven forming a complex pattern. The low stretch of PVC solid woven conveyor belts compared to multiply conveyor belts make it possible to design longer centre-to-centre distances to scale down tensioning devices. This is important when considering the usually cramped underground situations they operate in.

Depending on the kind of application, other parameters become important. For example, PVC conveyor belts can hardly be used for slopes, man-riding, or belt-to-belt drives. Also the carry-over of material is frequently a problem, because scrapers usually cannot cope with the uneven surface of PVC conveyor belts. Table 3 shows the properties of three belt families.

In general, practice shows that the operating life of Uniflex PVG conveyor belts is two to three times that of PVC conveyor belts and that of rubber multi-ply conveyor belts.

Splicing

PVG conveyor belts can be connected by vulcanisation or cold bonding or with mechanical fasteners. Most durable and efficient is the finger splice method using mobile curing presses (Figure 2).

The splice finger length depends upon the minimum belt breaking strength. Table 4 shows the dimensions for the different belt types. For example, 1000/1 means that the belt has got a minimum breaking strength of 1000 N/mm of belt width. Figures 3 shows how a splice is prepared.

Table 3. The properties of three belt families

Criterion	PVC	Rubber	PVG
Wear resistance	Poor	Good	Excellent
Robustness, impact and rip resistance	Good	Good	Excellent
Edge stability	Good	Poor	Excellent
Suitability for belt-to-belt drives	Poor	Excellent	Excellent
Suitability for man riding	Poor	Excellent	Excellent
Tracking stability	Good	Excellent	Excellent
Slope conveying	Poor	Excellent	Excellent
Cleanliness (carry-over)	Poor	Excellent	Excellent
Noise level	Poor	Excellent	Excellent
Elongation properties	Excellent	Good	Excellent

Table 4. Different belt dimensions

Belt type	Finger length (mm)	Finger width (mm)	Covering fabric length (mm)	Joint length (mm)
800/1	1000	60	1300	1500
1000/1	1200	60	1500	1700
1250/1	1500	60	1800	2000
1600/1	2000	70	2300	2500
2000/1	2400	70	2700	2900
2500/1	3000	70	3300	3500
3150/1	3800	70	4100	4300

Conclusion

In most countries the trend in underground coal mining has been to reduce the number of plies in a conveyor belt, with many multiply conveyor belts being replaced by modern two ply constructions.

With the birth of the single ply Uniflex PVG conveyor belt, an extremely efficient and reliable belt type is now available for the rough conditions in underground coal mining, representing the state-of-the-art technology. This conveyor belt type is an important contribution to the successful mechanisation of underground coal mining. ■

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